The Effect of Two Lensing Galaxies on the Time Delay in PKS 1830-211

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Abstract. The Einstein ring gravitational lens PKS 1830-211 has the potential to provide an accurate global value of Hubble's constant since the time delay and both the lens and background source redshifts are known. This paper estimates the Hubble constant based on a single-lens model and on two cosmological models. It also illustrates how the presence of the second, lower redshift intervening galaxy reduces the observed time delay and derived Hubble constant values.

The Einstein ring PKS 1830-211 is composed of two bright, compact radio sources separated by 1 arcsecond (the NE and SW components) and connected by a ring of radio emission at low frequencies. The redshift of the background source is 2.51 (Lidman, et al. 1999), and the redshift of the spiral galaxy producing the Einstein ring is 0.89 (Wiklind & Combes 1996). Thus, this lens system is distant enough to provide a global value of H_o. Radio variability monitoring has determined the time delay between the NE and SW components with $\approx 5\%$ accuracy (Lovell 1999).

The main lensing galaxy at $z = 0.89$ should be closer to the SW component than the NE component based on models of the lens system (Nair, et al. 1993) and on molecular radio absorption line observations. Indeed, the NICMOS images of PKS 1830-211 obtained by the CASTLES collaboration show a galaxy between the two lensed components, but somewhat closer to the SW component.

There is also a second, lower redshift ($z = 0.19$) intervening galaxy in this system, which is detected via HI absorption in front of the NE component (Lovell, et al. 1996). This galaxy may be responsible for the more complex and extended VLBI morphology of the NE radio component compared to the SW component. It has not been included in previous lens models for PKS 1830-211 or in initial estimates of H_o from this system.

The large-scale radio morphology of PKS 1830-211 can be fit reasonably well by single lens models, suggesting that the $z = 0.19$ galaxy does not have a large effect on the Einstein ring or the locations of the two bright radio components. If the $z = 0.19$ galaxy is located outside of the Einstein ring, but close to the NE component, it could explain the unusual VLBI morphology of this component without affecting the over-all size or shape of the Einstein ring. In this case it would also affect the observed differential time delay between the NE and SW components by contributing a larger additional time delay along the path to the NE component than along the path to the SW component.

The NE component leads the SW component in radio variability, so the effect of the $z = 0.19$ galaxy will be to reduce the observed differential time delay between the two components. In the absence of the z = 0.19 galaxy the observed time delay due to the z = 0.89 galaxy would be larger, leading to lower values of H_o derived from the Nair, et al. (1993) model.

The magnitude of the additional delay produced by the z = 0.19 galaxy depends on its mass and location. Deconvolved H and K band NICMOS images produced by the CASTLES group (Kochanek, et al. 1999) show extensions to the west of both the NE lensed component and the galactic M star just north of the NE component. Either of these would be plausible locations for the z = 0.19 galaxy. The galaxy at the bottom edge of the deconvolved NICMOS images is an unlikely candidate because it is closer to the SW lensed component and too far from both components. If we assume that the z = 0.19 galaxy is located at the position of the extension to the west of the NE component, it is about 0.23 arcsec from the NE component and 0.80 arcsec from the SW component. In this case the additional differential time delay is 1.43×10^{-10} M_{gal} days, where M_{gal} is the (unknown) mass of the z = 0.19 galaxy in $M_\odot$.

The table below show how severe the effect of the z = 0.19 galaxy could be. The first five lines of the table show that differing cosmological models have relatively little effect on the value of H_o. However, the last line shows the effect of assuming a mass of 10^{11} $M_\odot$ for the z = 0.19 galaxy, which changes the differential time delay by 14 days. The reduction in the derived H_o values is dramatic. It is clear that additional observations to better constrain the location and mass of the z = 0.19 galaxy will be needed before an accurate estimate of H_o will be possible with this lens system.

Effect of Cosmological Models and Time Delays

Cosmology:	Conventional CDM ($\Omega_M = 1.0,\ \Omega_\Lambda = 0.0$)	Accelerating ($\Omega_M = 0.3,\ \Omega_\Lambda = 0.7$)
Ang. dia. dist., z = 0.19	420 h^{-1} Mpc	459 h^{-1} Mpc
Ang. dia. dist., z = 0.89	865 h^{-1} Mpc	1123 h^{-1} Mpc
Ang. dia. dist., z = 2.51	797 h^{-1} Mpc	1164 h^{-1} Mpc
$\Delta\tau$ from Nair model	17 h^{-1} days	19 h^{-1} days
H_o for $\Delta\tau = 24$ days †	71 km s^{-1} Mpc^{-1}	79 km s^{-1} Mpc^{-1}
H_o for $\Delta\tau = 38$ days ‡	45 km s^{-1} Mpc^{-1}	50 km s^{-1} Mpc^{-1}

† Delay measured by Lovell (1999). ‡ Maximum delay without z=0.19 galaxy.

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